Olympus

Technology Roadmap

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Document History			
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Table of Contents

Introduction

- The following is a technology roadmap for the Olympus program and includes:
  - Background Information
    - What is Olympus? - concepts and requirements that define the technology needs
  - The Roadmap Organization
  - The Roadmap
    - Technology needs based on mission and science requirements
  - If you have any comments or questions contact:
    - Otto Bruegman, bruegman@itmi1.com, Ph. # 301-474-6060

  - For future updates to the Roadmap and to view it on the Web go to http://lheawww.gsfc.nasa.gov/docs/balloon/technology_roadmap/index.htm

Background

- Olympus offers a launch platform
  - With low non-science costs
  - Enabling first rate science in many disciplines
  - Capabilities comparable with space-based platforms with added flexibility
    - Payload return
    - Temporal/thermal stability
    - High mass, large volume experiments

Background

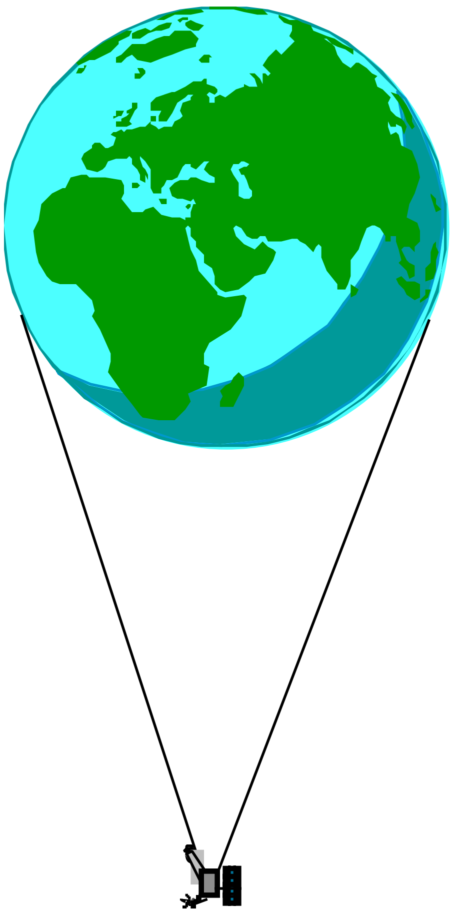
- Olympus provides a launch capability that complements the goals of the Explorer Program -

  <Excerpt from 1998 University-class Explorer Announcement of Opportunity (AO 98-OSS-1)>

  - A long duration balloon may be proposed as the launch vehicle for a University-class Explorer. For this AO, a long duration balloon flight is defined as a balloon flight lasting more than one week. A complete mission using long duration balloons may include more than one flight as long as the first flight is no later than June 30, 2001, and the total investigation stays within the cost caps.
  - [Olympus] offers an alternative launch platform for technology and science experiments for all Explorer class missions (University Explorers: UNEX, Small Explorers: SMEX, Medium Explorers: MIDEX).

Background

- Olympus
  - Model for balloon borne science
  - Greater than 2000 LB. Payload
  - Greater than 90,000 ft. (>150,000 ft. goal)
  - Greater than 100 day mission duration (>1000 day goal)
  - Non-science cost less than 10% of total mission costs.



Olympus Mission Concepts

- Science missions require both polar and mid-latitude capabilities thereby splitting Olympus into two broad functional blocks:
  - Polar (latitudes > ±70°)
  - Mid-latitudes (latitudes ≤ ±70°)

Polar Missions

- Typical Mission Scenario
  - Principal Investigator (PI) science gets funded for from Explorer, Earth System Science Pathfinder (ESSP), Discovery or other project (Funding is for science using Olympus launch and support)
  - Launch options
    - From site - Antarctica
      - Requires Dec., Jan., Feb., launch
    - From Christ church New Zealand
      - Steer to > 70° south latitude (~7 days)
      - Observe until Batteries low (1-2 weeks)
      - Maneuver to lower to recharge batteries
      - Maneuver back to > 70° south latitude
      - Repeat until program complete or Antarctica night is over
      - Battery recharge maneuver not required for day observing
      - Maneuver to Alice springs Australia to terminate mission (~7-14 days)
      - Land at a specific site

Mid-Latitude Missions

- Typical Mission Scenario
  - PI science gets funded from Explorer, ESSP, Discovery or other project (Funding is for science using Olympus launch and support)
  - Launch from a site (e.g. Alice Springs, Australia)
  - Early flight checkout of 5 hours to 2 days line of sight contact
  - Circumnavigate Earth several times with periodic return of data to PI
  - Land at a specific site (could be Alice Springs again)
  - Fly the next manifested PI mission

Mission Driven Requirements

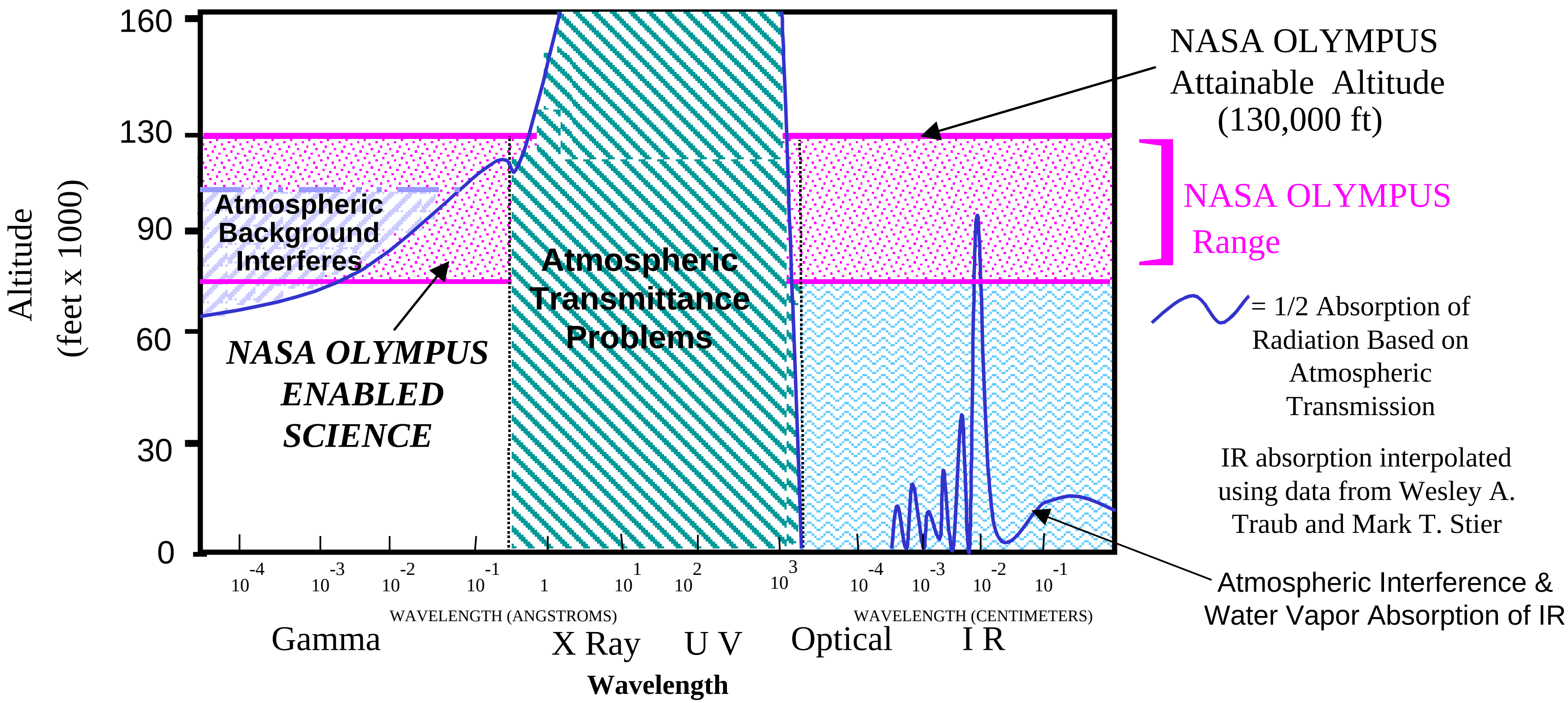
- Polar Unique
  - Power problems during polar night
  - Limited communications options
- Mid-latitude Unique
  - Altitude control systems
  - Lightning strike hardened systems
  - Termination systems for unauthorized air space
- Common to Both
  - Trajectory prediction and control
  - Balloon designs supporting > 100 day flights
  - Robust launch system
  - Protection from static discharge upon launch
  - Communications
  - Thermal control
  - Landing/recovery systems

Science Mission Concepts

- Science mission needs identified through
  - 1996 Science Workshop
  - Study Team research efforts
  - Continual interaction with science community
- Science needs, depending on mission, can be met by using one or both of the two mission concepts:
  - Polar (latitudes > ±70°)
  - Mid-latitudes (latitudes ≤ ±70°)
- Demonstration flight selected for 2001

Science Enabled at Olympus Altitudes

NASA OLYMPUS Enabled Science



- For wavelengths between 20 and 1200 Å a spacecraft is needed

Science Driven Requirements Areas

- The Science Concepts yielded varying requirements in the following areas:
  - Mission duration >100 days
  - Pointing
  - Trajectory
    - Altitude
    - Latitude
  - Data rate, collection and return
  - Command frequency
  - Command and Control
  - Power
  - Weight
  - Thermal
  - Field of View

Next Step

- To achieve Olympus mission goals
  - A 100 day balloon demo mission is being developed (ULDB)
  - Also need to:
    - Develop enabling technologies
    - Remain within cost boundaries
    - Accomplish within reasonable time frame
- Based on these needs, this technology roadmap was developed

Roadmap Organization

- Technology Areas based on mission and science requirements are identified
- For each Technology Area,the following topics are discussed:
  - Critical Requirements
  - Enabled science
  - Technologies under consideration
  - What is needed
  - Technical goals
  - Today's State-Of-The-Art (SOTA)
  - Technology Readiness Levels (Defined on the next page)
  - Cross cutting applications

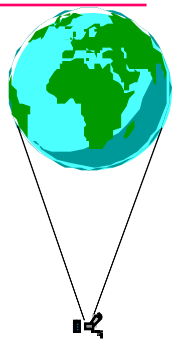
Technology Readiness Levels
Definition

Basic Technology Research	**LEVEL 1**	BASIC PRINCIPLES OBSERVED AND REPORTED
Research To Prove Feasibility	**LEVEL 2**	TECHNOLOGY CONCEPT AND/OR APPLICATION FORMULATED
	LEVEL 3	ANALYTICAL & EXPERIMENTAL CRITICAL FUNCTION AND/OR CHARACTERISTIC PROOF-OF-CONCEPT
Technology Development	**LEVEL 4**	COMPONENT AND/OR BREADBOARD VALIDATION IN LABORATORY ENVIRONMENT
Technology Demonstration	**LEVEL 5**	COMPONENT AND/OR BREADBOARD VALIDATION IN RELEVANT ENVIRONMENT
	LEVEL 6	SYSTEM/SUBSYSTEM MODEL OR PROTOTYPE DEMONSTRATION IN A RELEVANT ENVIRONMENT (Ground or Space)
System/Subsystem Development	**LEVEL 7**	SYSTEM PROTOTYPE DEMONSTRATION IN A SPACE ENVIRONMENT
System Test, Launch and Operations	**LEVEL 8**	ACTUAL SYSTEM COMPLETED AND "FLIGHT QUALIFIED" THROUGH TEST AND DEMONSTRATION (Ground or Space)
	LEVEL 9	ACTUAL SYSTEM "FLIGHT PROVEN" THROUGH SUCCESSFUL MISSION OPERATIONS

Technology Areas
Based on Mission & Science Requirements

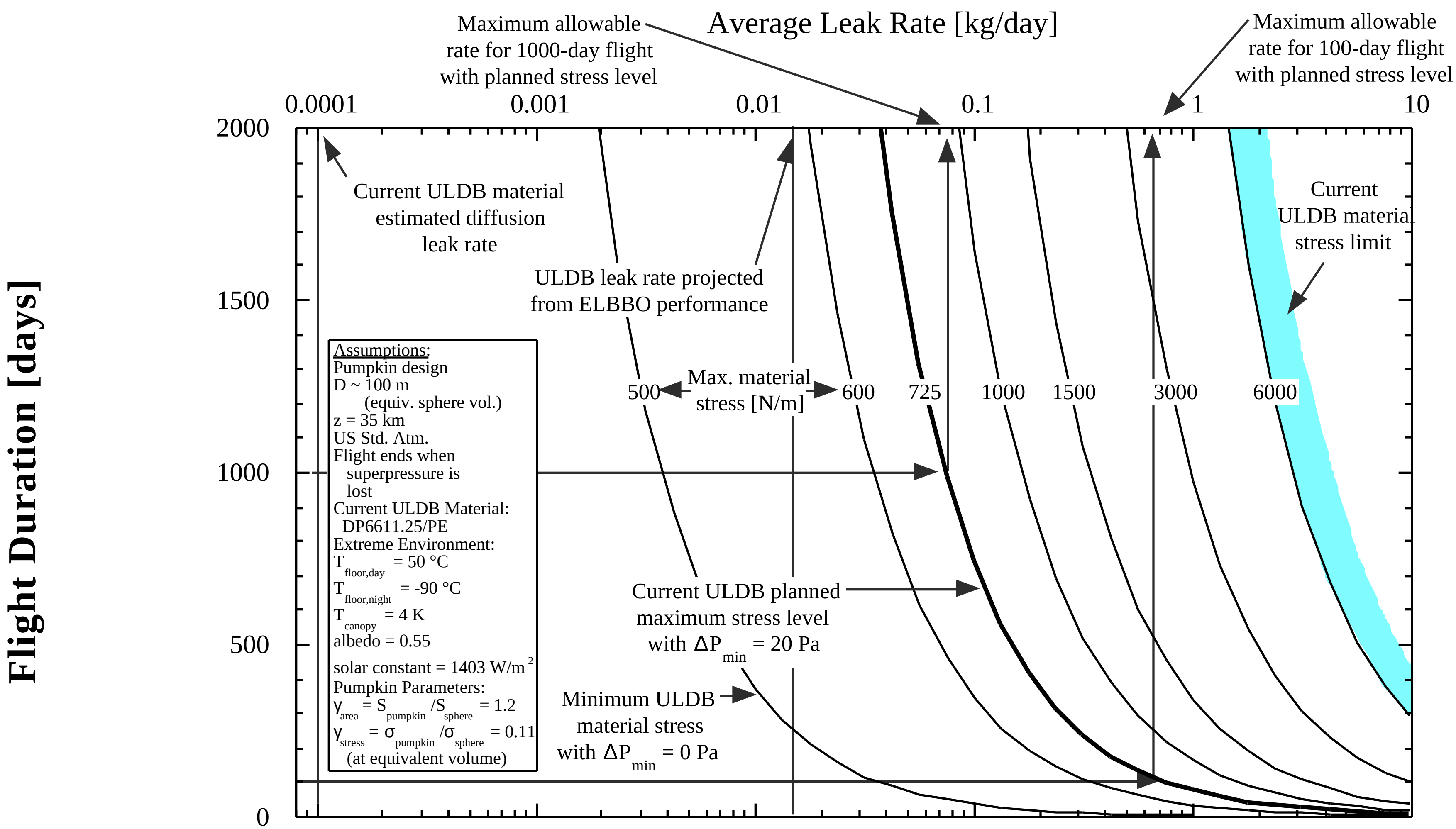
- Balloon
- Trajectory Prediction & Control
  - Latitude & Altitude Control
  - Weather Prediction
- Power
  - Generation
  - Storage
  - Management & Distribution
- Communications
  - Data collection
  - Data return
  - Command & control
- Thermal
- Pointing Systems
- Termination & Recovery Systems
- Launch Systems
- Balloon Obstruction of Field of View (FOV)
- Operations Autonomy

Balloon



- Critical Requirements
  - 100 day flight capable
  - Need higher altitudes to enable more science disciplines
  - Need greater mass capability to enable better science
- Enabled Science
  - Altitude ≥ 120,000ft, 20Kev-20Mev(Gamma & Cosmic Ray), <120,000 background from atmospheric swamps detectors
  - < 140,000 ft atmosphere absorbs Ultraviolet & X-ray
  - All visible and Infrared wavelengths are observable from Olympus
- Technologies under consideration
  - Balloon manufacturing processes & technologies

Mission Duration vs. Material Strength and Balloon Quality

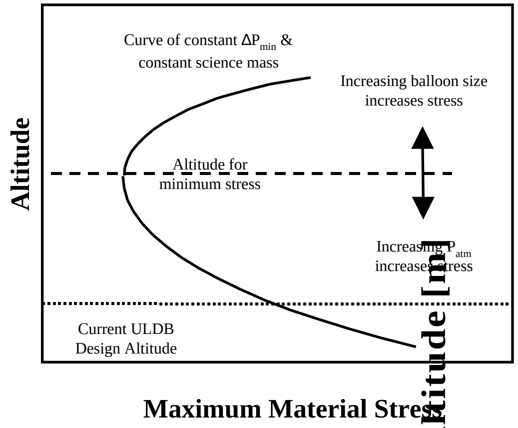


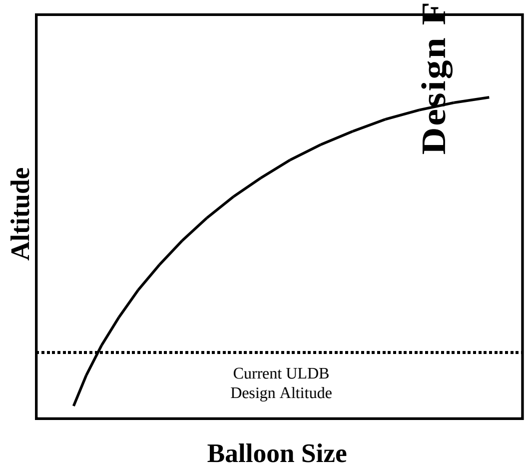
Higher Balloon Quality

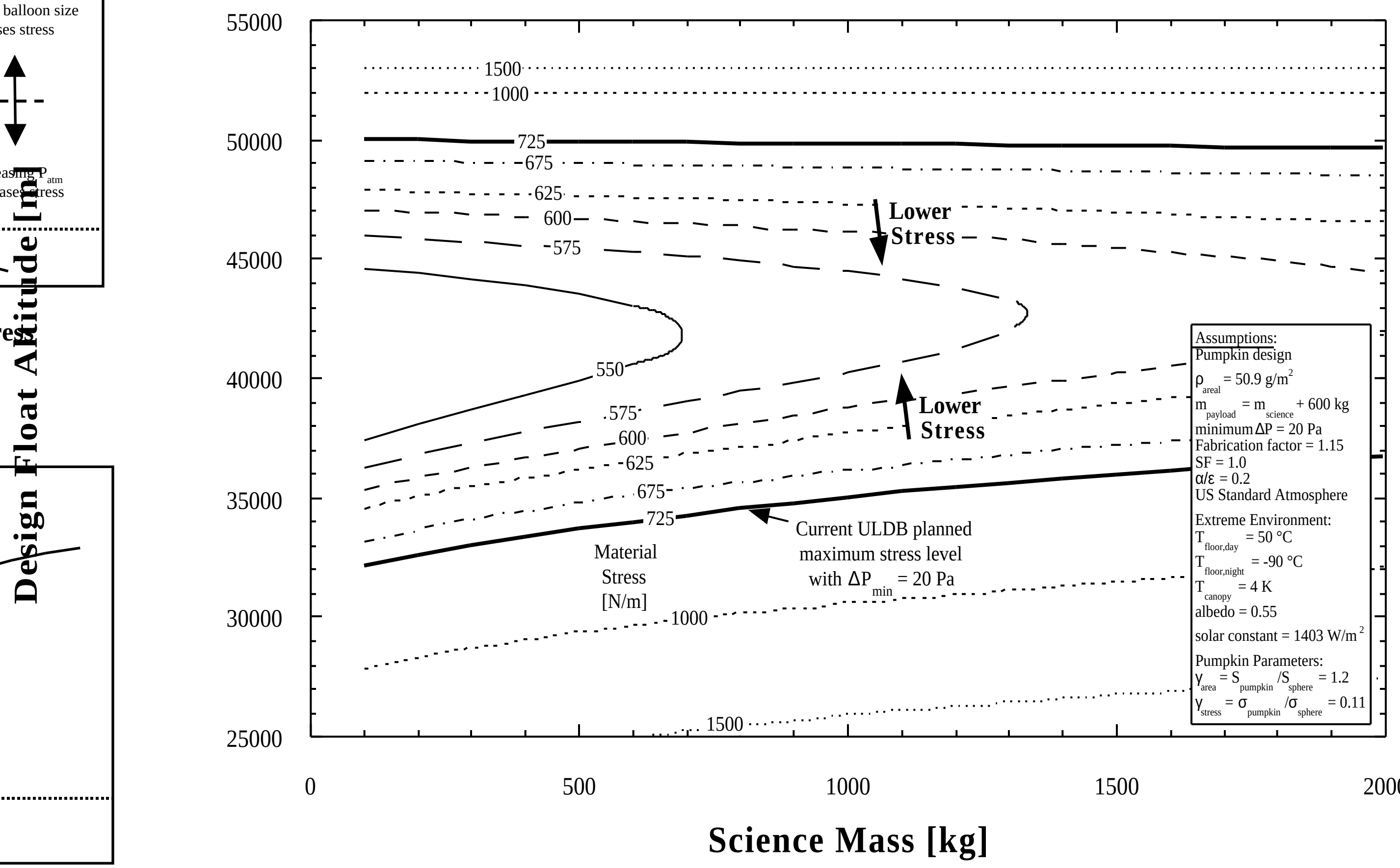
(Lower leak rates equate to fewer manufacturing defects)

Roadmap

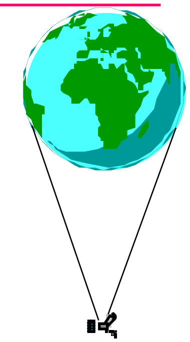
Effect of Science Mass and Altitude on Stress







Balloon Manufacturing Processes & Technologies



What is needed

- Advances are needed in:
  - Balloon composites & components
  - Seaming techniques
  - Automated manufacturing process
  - Quality control
  - Balloon modeling tools

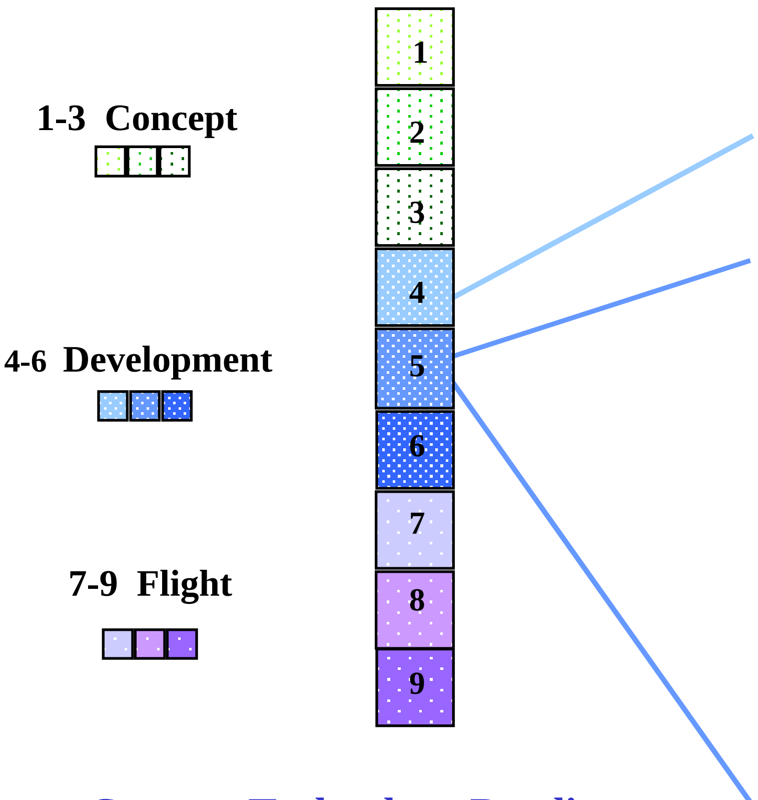
Today's State of the Art

- Fabric (62 g/m^2)
- Material Strength
  - 7600 N/m Ultimate
  - 2400 N/m "Yield"
- Bi-tape manual seam

Technology Goals

- Decreased composite weight
  - 40 g/m^2 for 2700 kg to 38,000 m
  - Higher Strength/Weight Ratio
- Non degrading at operational altitude
- Uniform, low stress seams
- Automated (consistent) high quality seaming

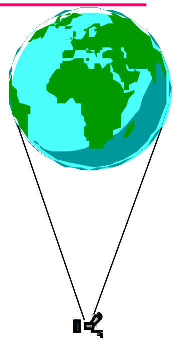
Balloon Manufacturing Processes & Technologies



Current Technology Readiness Levels (TRLs)

Technology Required	***"Needed By"***
– Automated Seaming	– 2000
– Fabric	
• Light Weight & High Strength able to attain:	
– 100 day flights	– 2000
– 33,500m (110,000 ft)	– 2000
– Lift 900kg (2000 lbs)	– 2000
– 1000 day flights	– 2005
– 38,000 m (125,000 ft)	– 2005
– Lift 2700kg (6000 LB)	– 2005
– 42500m (140,000 ft)	– 2010
– Quality Control Techniques	– 2000

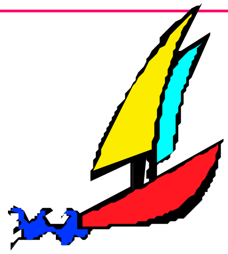
Balloon Manufacturing Processes & Technologies



- Cross Cutting Applications:
  - Earth Science Missions
  - Planetary Missions

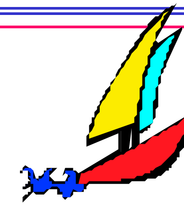
- Technology Transfer External to NASA:
  - Telecommunication Industry

Trajectory Prediction & Control



- Critical Requirements: *(requirements vary across missions)*
  - Avoid no-fly zones.
  - Keep experiment in a desired latitude and/or altitude range.
  - Perform station keeping.
  - Enable launch & land at same or different stations.
  - Enable landing at specific sites.
  - Enable high % payload recovery.
- Enabled Science
  - Station keeping enables ultra-high data rate science via line-of-sight communication
  - Antarctic day flights
  - In-situ atmospheric studies
  - Survey missions and observatory class (e.g., SOFIA type) missions
- Technologies under consideration
  - Prediction systems, simulation systems, latitude control systems, altitude control systems, ...

Trajectory Control:
Latitude & Altitude Control



What is needed

- Accurate trajectory forecasts to Several days out
- Methods to control latitude trajectory
- Altitude control system
- Enhancements that can benefit current zero pressure balloon flight operations

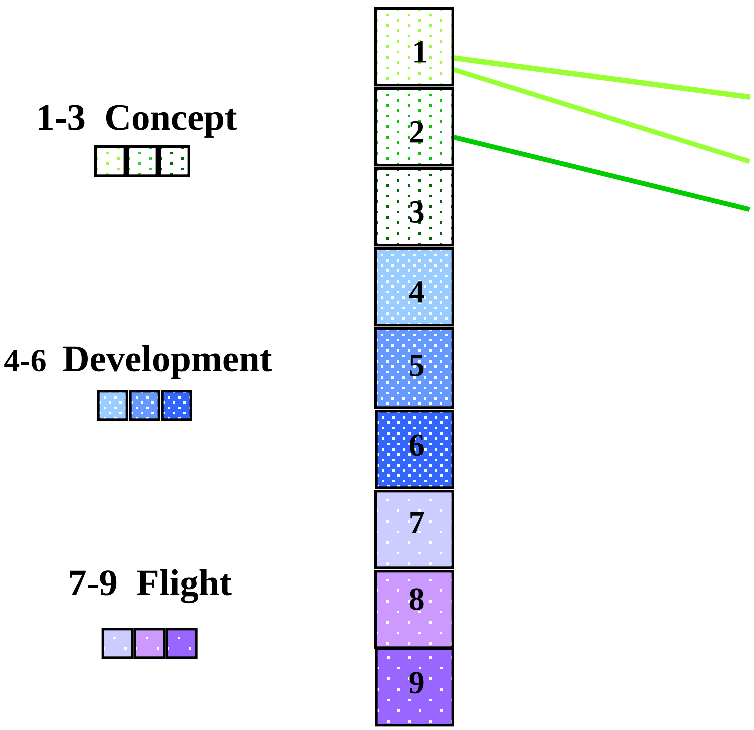
Today's State of the Art

- Trajectory prediction good for 1-3 days out.
- Latitude control - none
- Altitude control - ballast / lifting gas release

Technology Goals

- Trajectory prediction several days out
- Control over flight trajectory
- Enhanced altitude control

Trajectory Control:
Latitude & Altitude Control



Current Technology Readiness Levels

Technology Required	***"Needed By"***
– Latitude Prediction	– 2002
– Latitude Control	– 2004
– Superpressure Balloon Altitude Control	
• 20,000 ft	• 2002
• 60,000 ft	• 2005

Trajectory Control:
Weather Prediction

What is needed

- Methods to control latitude
- Altitude control systems for superpressure balloons
- Windsails
- Propulsion systems
- New Balloon designs

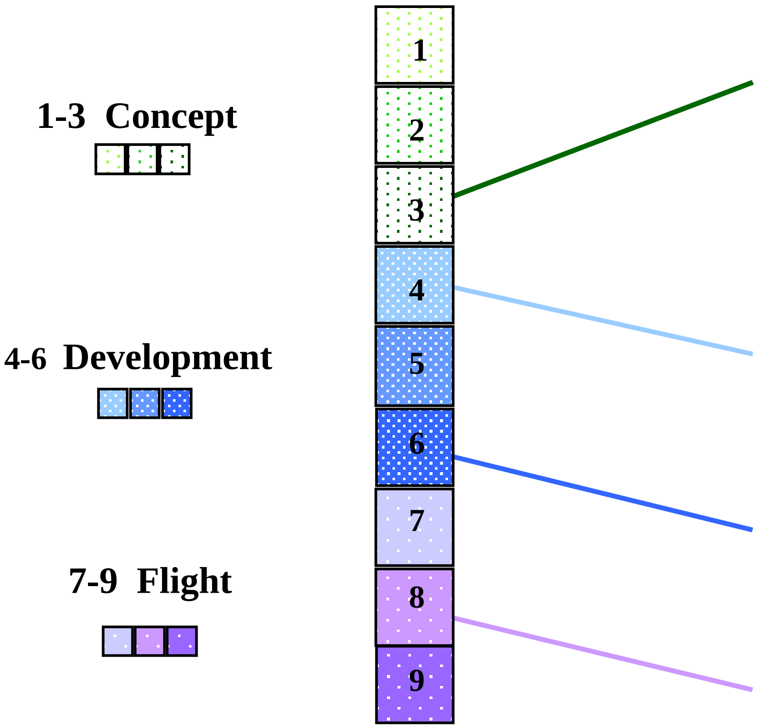
Today's State of the Art

- Prediction/Simulation code good for 1-3 days out.

Technology Goals

- Wind predictions & trajectory simulations for balloon guidance
- Stratospheric weather forecasting
- Improve horizontal resolution (1 degree) w/model top at 0.1 kpa (65 km)
- New model with dynamic core.

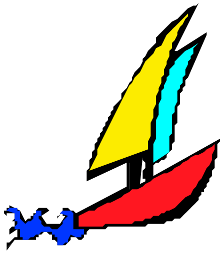
Trajectory Control: *Weather Prediction*



Technology Required	*"Needed By"*
– Stratospheric weather forecasting	
• 30-40 km	• 2002
• 20-50 km	• 2008
– 1 to 2 week wind vector predictions	– 2000
– 2 to 3 day wind vector predictions	– 2003
– Wind vector knowledge	– 2000

Current Technology Readiness Levels

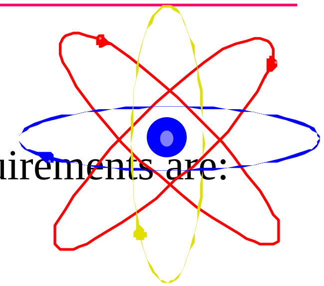
Trajectory Control



- Cross Cutting Applications:
  - Earth Science Missions
  - Planetary Missions

- Technology Transfer External to NASA:
  - Telecommunications Industry

Power Systems



- **Critical Requirements**
  - Power Requirements vary across missions. Some of the more critical requirements are:
    - Greater than 1000 watts
    - Continuous power during polar night (6 months)
    - Increased efficiency for solar arrays
    - Deep battery discharge for 12 hour day/night cycle
  - Power generation and power management systems for mid-latitude and arctic nights
- **Enabled Science**
  - IR radiative mirror cooling
  - Reduced zodiacal light
  - Polar night observations
    - Optical & IR studies of very faint objects
    - Long term studies of Active Galactic Nuclei (AGN) in Ultra Violet (UV)
- **Technologies under consideration**
  - These requirements need advances in, solar arrays, fuel cells, batteries, flywheels, Radial Thermal Generation (RTGs)...

Power Generation

What is needed

- Advances are needed in:
  - Solar arrays: Inflatable solar arrays and thin film solar cells
  - Fuel cells: Air breathing at high altitude, high power, no hydrogen sources
  - RTGs
  - Tethered Windmills?

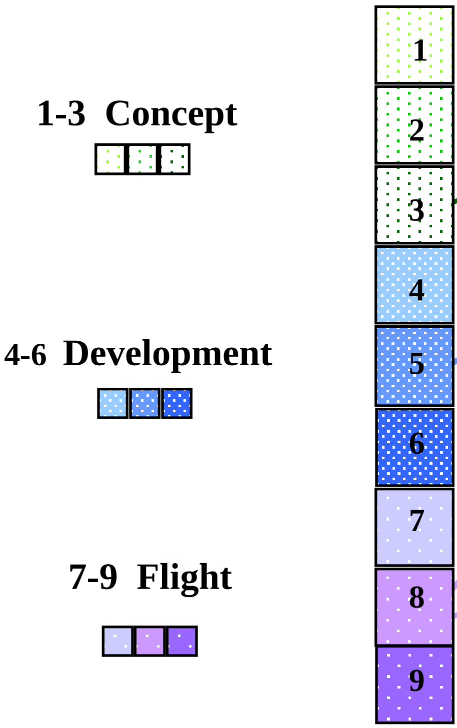
Today's State of the Art

- Solar arrays:
  - GaAs/Ge Solar Cells
  - 60 W/Kg Solar Arrays
- Fuel Cell Technologies
  - Hydrogen-Oxygen Proton membrane
  - Water-Methanol-Air
  - Methanol-Formaldehyde
  - Hydrogen-Oxygen (Metal hydride storage) 600 W/Hrs/Kg

Technology goals

- Solar Arrays:
  - 300 W/Kg, 25% efficiency
  - 600 W/Kg, 30% efficiency
  - 1000 W/Kg, 35% efficiency
- Fuel cells: use kW-hrs/kg and duration
- RTGs:
  - Half life of fuel less than one year
  - Efficiency of 30 - 40%
  - Political acceptability
  - Using thermal dynamic cycle radiators

Power Generation

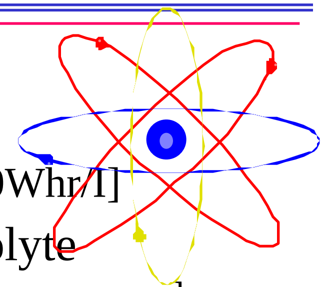


Current Technology Readiness Levels

Technology Required | ***"Needed By"***

- Short half-life fuel, ultra-high efficiency RTG – 2000
- Fuel cells (PEM)
- Conventional batteries
  - TBD W/Kg, TBD efficiency
- Conventional Solar cells
  - 300 W/Kg, 25% efficiency – 2000
  - 600 W/Kg, 30% efficiency – 2005
  - 1000 W/Kg, 35% efficiency – 2010

Power Storage



What is needed

- Rechargeable Lithium Batteries
- Flywheels
- Molten Salt

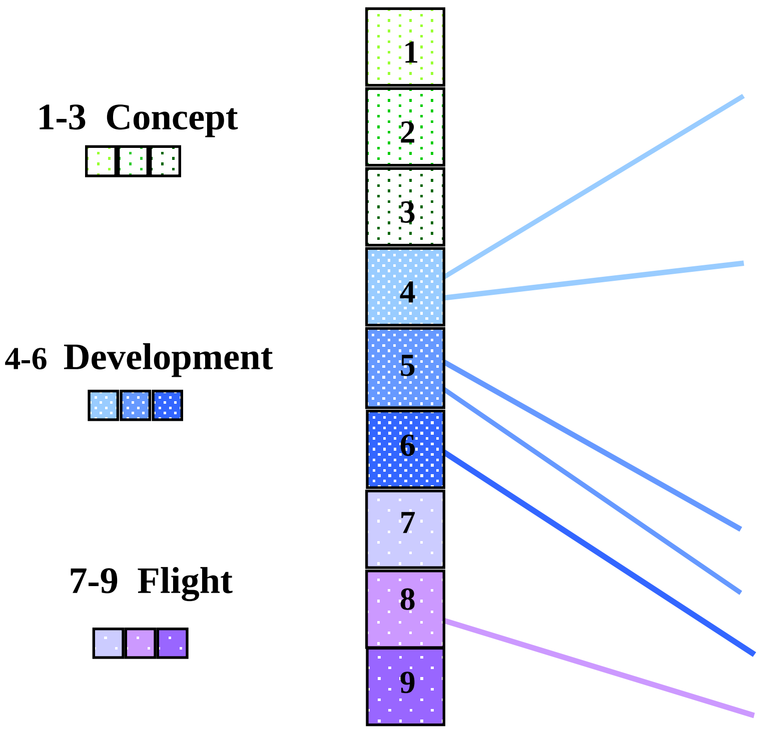
Today's State of the Art

- NiH_2 Batteries [40 W-hr/kg, 30Whr/l]
- Li-ion solid polymer electrolyte
  [Working on cell charge & safety for space use]
- Metal hydride alloy + NiH technology
  [Electric vehicle application, 95 W-hr/kg]
- Magnetic bearing flywheels [44 W-hr/kg with 90% depth-of-discharge]

Technology Goals

- Battery power ratings
  - 85 W/Hr/Kg
- Available 2000

Power Storage



Current Technology Readiness Levels

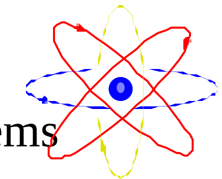
Technology Required	***"Needed By"***
– Frictionless, superconducting bearing flywheels	– 2003
– Superconducting power storage	
• 100 W-hr/kg	• 2000
• 200 W-hr/kg	• 2005
– Magnetic bearing flywheel	– 2000
– Li-ion polymer	– 2000
– NiMH	
– $Ni\text{-}H_2$	– currently exist

Power Management & Distribution

What is needed

- High efficiency converters
- Tailored bus converters
- High density packaging
- Reversible fuel cells

Today's State of the Art



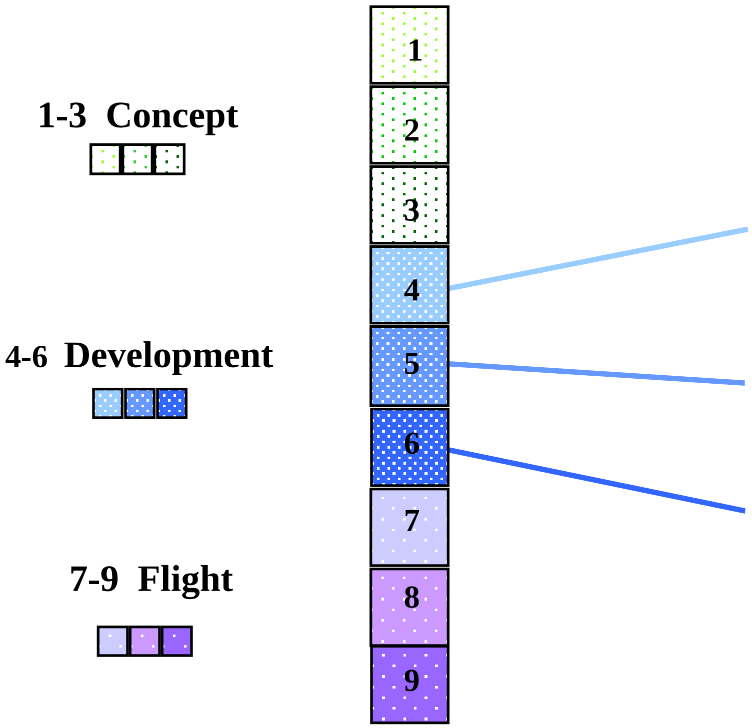
- 28B. 90% INTER CONV. Systems
- 200W/Kg PMAD

Technology Goals

- Low Cost Reliable, safe Power systems

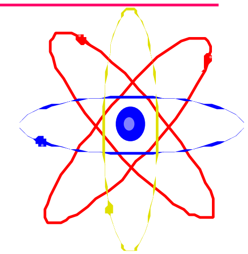
Power Management & Distribution

Technology Required	*"Needed By"*
– Superconducting power storage	– 2001
– Reversible Fuel Cells	– 2000
– High Efficiency Converters	– 2000



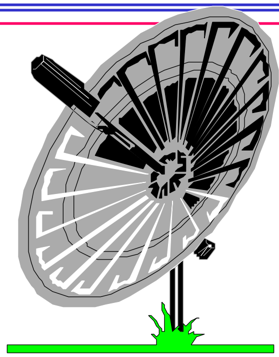
Current Technology Readiness Levels

Power Systems



- Cross Cutting Applications:
  - Inflatable Arrays : New Millennium
  - PowerSat: Commercial applications
  - Fuel Cells: Automobiles, the drone, planetary balloons
  - Batteries
  - Remotely Piloted Vehicles
- Technology Transfer External to NASA:
  - Telecommunications

Communications



- **Critical Requirements**
  - Tera-bytes of data to the scientists over a 100 day mission
  - Return data often enough to ensure mission success if payload is lost
  - Command and control requirements will very according to science:
    - Range from autonomous operations to near real time command and control
    - Near constant knowledge of balloon craft position required for safety
- **Enabled Science**
  - Solar studies
  - Interferometers
  - Downward looking imagers
  - All Polar flights - in data and in command and control
- **Technologies under consideration**
  - Polar Tracking & Data Relay Satellite (TDRS) coverage and Low Earth Orbit (LEO) polar communications satellites
  - TDRS demand access capability
  - New commercial communications systems being put in place in the next five years
  - Data storage and drop

Data Return

What is needed

- Return of on board (Terabytes) data
- Large deployable antennas
- Phased array antennas
- Portable high rate ground station
- High power transmitters

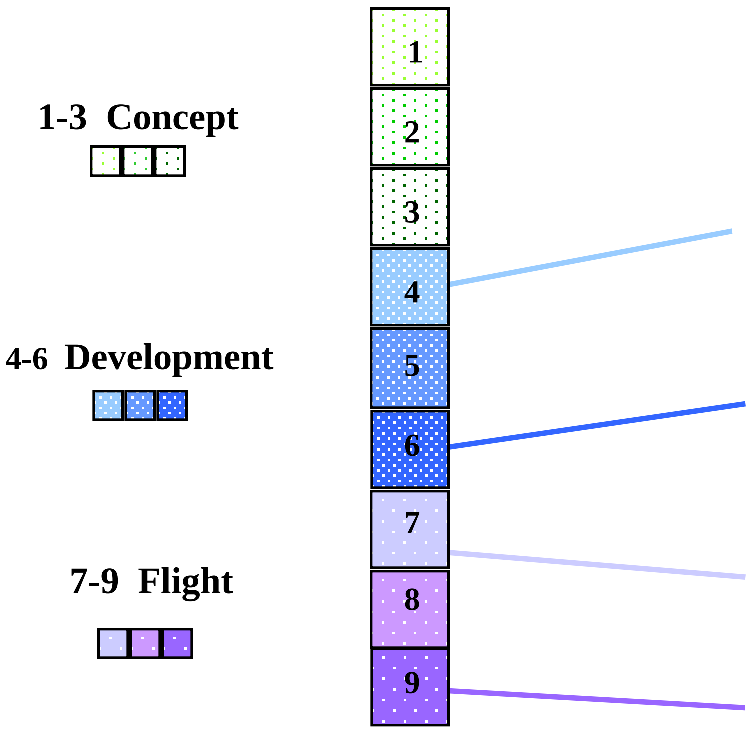
Today's State of the Art

- At the Poles
  - TDRS 3.6 hours/day
  - 150 kbps MA
- Mid and low latitudes
  - TDRS and other geosynchronous communications satellite services

Technology Goals

- Burst data return
  - Via RF link
  - Via media drop
- Quasi-real time operations with ultra-high rates

Data Return



Current Technology Readiness Levels

Technology Required	*"Needed By"*
– Ultra-high rate	– 2003
– Low cost TDRS transponder	– 2000
– 150 kbps Multipurpose access (MA) at S. Pole	– currently exist
– 50 kbps Multipurpose access (MA) at S. Pole	– currently exist

Data Collection

What is needed

- On board (Terabytes)
- Interface for data return (Terabytes)

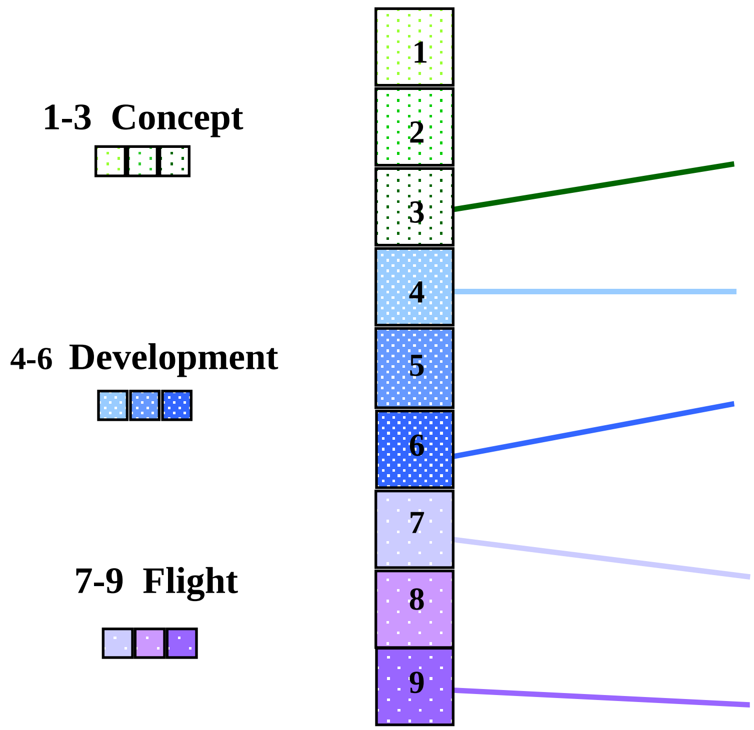
Today's State of the Art

- Storage Capacities range from a few gigabytes to several hundred. Some examples are:
  - DLT7000 - 35GB, SuperDLT tapes 100-500GB,
  - Optical disk drives can hold up to 1 Terabyte but are cost prohibitive under current balloon budget.
  - Hard disks can hold 18 GB each and can be stacked; but not on current not balloon budget.

Technology Goals

- On-board storage of:
  - 1 TB on a "3480-size" cartridge
  - 1 TB on a 14" platter
  - 100 Terabytes
- Storage systems that can operate in near vacuum
- Cost effectiveness

Data Collection



Current Technology Readiness Levels

Technology Required	*"Needed By"*
– 100 Terabytes	– 2005
– 1 TB on a 14" platter	– 2002
– 1 TB LOTS Worm Technology	– 2001
– 100 BGB Super DLT	– currently exists
– 1 TB Optical Tape	– currently exists

Command & Control

What is needed

- System to remotely control balloon craft
  - For safety
  - For trajectory control
- Capability for flight planning and command load generation from planning inputs
- Capability to provide minimal/emergency instrument monitor and control or full control of science program according to PI needs.

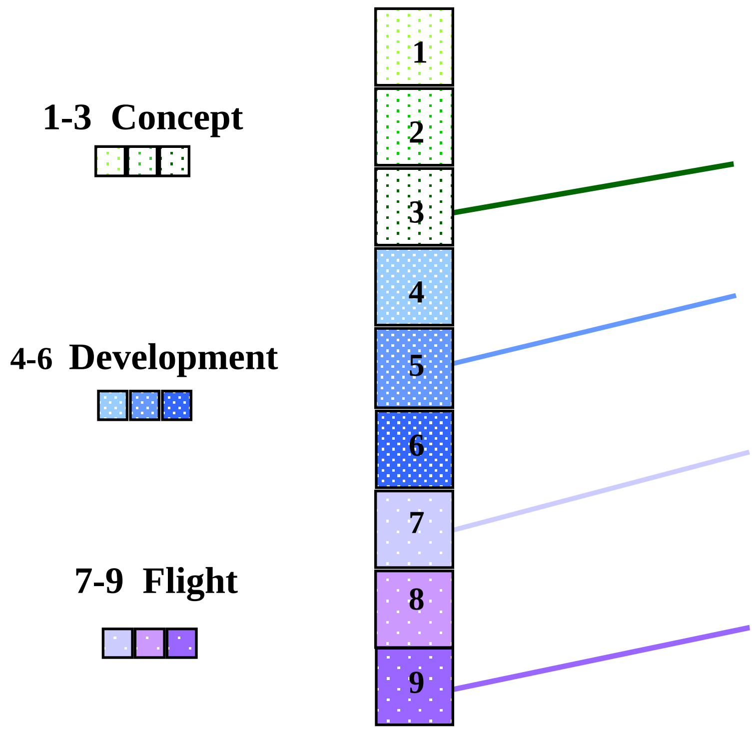
Today's State of the Art

- Several companies provide COTS systems with control center operations
- At least one system integrates instrument ground control and onboard but is not least expensive
- Provide an interface for PIs who require direct control of instruments

Technology Goals

- Provide a system that is responsive to support safe balloon craft, instrument and operation
- Automated operations to minimize operator direct involvement and key personnel during off shift periods
- Provide capability to manage a range of instruments

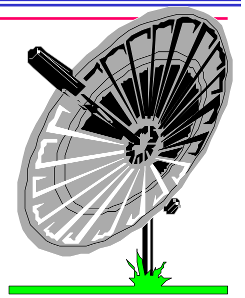
Command & Control



Current Technology Readiness Levels

Technology Required	*"Needed By"*
– Trajectory Control	– 2005
– Global low rate forward & return links	– 2001
– Instrument control from PI home institution	– 2001
– LOS & low rate comm (not world wide)	– currently exists

Communications



- Cross Cutting Applications:
  - Magnetic disk recorder pressurization: Space missions.
- Technology Transfer External to NASA:
  - Application of commercial services: Low to medium altitude space missions.

Thermal

- **Critical Requirements**
  - Robust thermal control supporting 12 hour day-night cycles for 100 days at lower latitudes and 100 days of full sun or continuous dark at Polar latitudes.

- **Enabled Science**
  - High powered instruments
  - Detectors requiring extreme low temperatures

- **Technologies under consideration**
  - Propane cycle heat pump

Thermal

What is needed

- Non-cryogen cooling systems providing
  - Longer operation than cryogen systems
  - Lower weight than cryogen systems
- Mechanical coolers for instruments
  - Cryocoolers
- Low-power, active thermal control
  - Circulating coolant loops in 1g environment
  - Heat pipes

Today's State of the Art

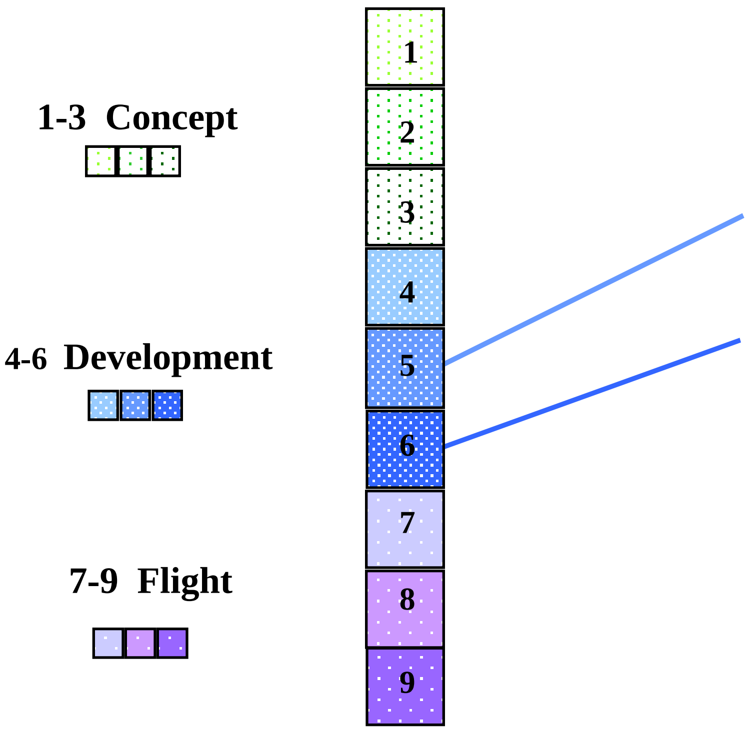
- Vapor compression heat pump is a mature, ground proven system. Not yet flight proven.

Technology Goals

- Maintain 0-35°C for balloon craft and instrument electronics
- Cool instruments to 70K - 4K

Thermal

Technology Required ***"Needed By"***

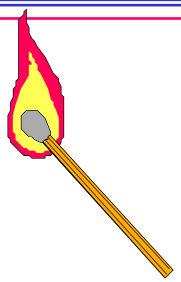


Current Technology Readiness Levels

- Circulating coolant loops – 2001
- Cryocoolers
  - Maintain 0-35 C for balloon and instrument electronics
    - ±10ºC – 2002
    - ±1ºC – 2007
  - Cool instruments to 70K-4K
    - Cool 5 Watts of input load to 70 K – 2002
    - Cool 1 Watt of input load to 4K – 2005

Thermal

- Cross Cutting Applications:
  - Space and planetary explorations



- Technology Transfer External to NASA:

Pointing Systems

- **Critical Requirements**
  - 10th of an arcsecond gondola pointing
  - Pointing systems that operate in a 1-g environment.
- **Enabled Science**
  - Better than Space Telescope type imaging
  - Interferometry
  - Large interferometers for planet searches
  - Hard X-ray and gamma-ray imaging instruments
- **Technologies under consideration**
  - Low torque decouplers to separate balloon from payload
  - Torque unloading systems, e.g., cold gas thrusters, magnetic torque, sails or rotary fans
  - Daytime aspect sensors - enables hard X-ray and gamma-ray imaging instruments
  - Motion sensor systems such as gyroscopes, differential Global Positioning System (GPS), & precision solid state accelerometers
  - High torque, high capacity, low noise momentum wheels

Pointing Systems

What is needed

- Methods to unload rotational torque from wind sheer.
- Sensors and control systems to detect and mitigate gondola motions.
- A method to remove tipping or tilting torque

Today's State of the Art

- Pointing the gondola to within 30 arcseconds on the sky has been achieved without secondary pointing.
- Pointing to within 1 arcsecond has been achieved, but currently requires the science instrument to correct for the gondola motion

Technology Goals

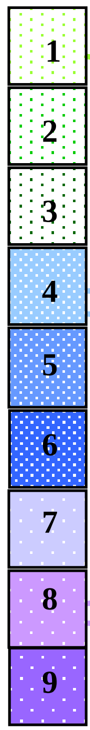
- Control gondola pointing to:
  - 10 arcseconds
  - 1 arcsecond
  - 0.1 arcsecond

Pointing Systems

1-3 Concept

4-6 Development

7-9 Flight



Current Technology Readiness Levels

Technology Required	*"Needed By"*
– Sails or rotary fans	– 2005
– Cold gas thrusters	– 2001
– Precision solid state accelerometers	– 2001
– Momentum wheels	– 2000
– Differential GPS to control gondola pointing to:	
• 10 arcseconds	• 2000
• 1 arch second	• 2001
• 0.1 arcsecond	• 2003

Roadmap

Pointing Systems

- Cross Cutting Applications:
  - Planetary balloons
  - Low cost space missions

- Technology Transfer External to NASA:

Termination & Recovery Systems

- **Critical Requirements**
  - Safety
  - State Department concerns (controlled overflight and no-fly zone avoidance)
  - Recover
    - For re-flight
    - For data return
- **Enabled Science**
  - Reusable observatory class payloads
  - All science topics can benefit from shared payload costs
- **Technologies under consideration**
  - Secure termination
  - Recovery - water and land
    - Shock absorber systems
    - Systems to find lost payload
  - Drop footprint

Termination & Recovery Systems

What is needed

- Global Positioning System (GPS) guided payload parasail
- Secure destruction systems to prevent inadvertent technology transfer
- Ground penetration shock absorbers
- Recovery beacons that can survive and operate for a long duration in extreme environments
- Contamination Shield

Today's State of the Art

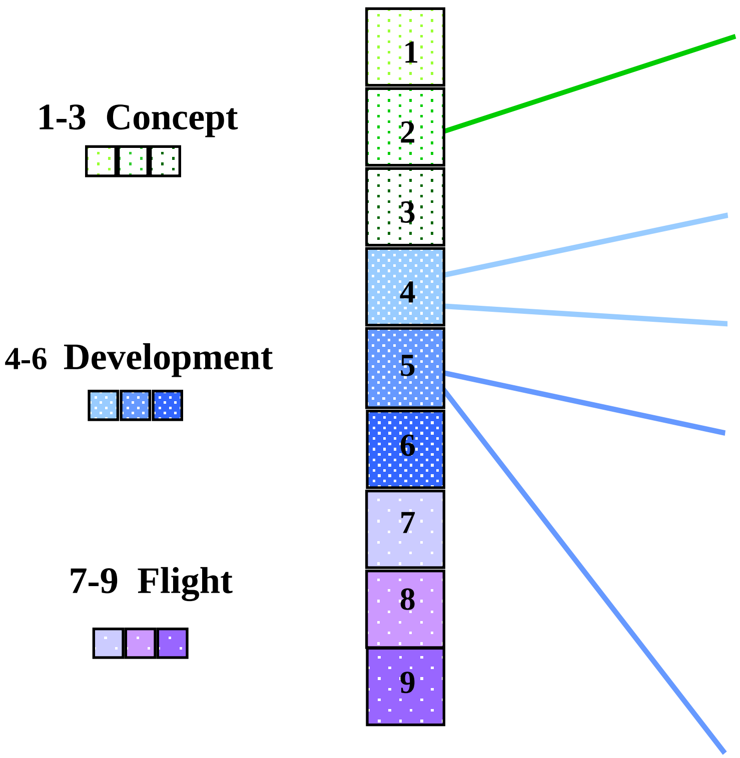
- Cut and drop gondola
- Use a parachute
- Currently developing a parasail system

Technology Goals

- Land payload in targeted area
  - 1 mile target area - within 20 mile radius from drop point
  - 500 ft. - 30 mile radius
  - 10 ft. - 50 mile radius
- Extreme environment beacon
- GPS location phone home system
  - Above system with 1 year life

Roadmap

Termination & Recovery Systems



Current Technology Readiness Levels

Technology Required	*"Needed By"*
– Ground penetration shock absorbers & contamination shield	– 2003
– Extreme environment beacon	– 2003
– GPS phone home system	– 2003
• With 1 year life	• 2005
– Parasail to land payload in	
• 1 mile target area within 20 mile radius from drop point	• 2001
• 500ft - 30 mile radius	• 2004
• 10 ft - 50 mile radius	• 2007
– Secure destruction systems to prevent inadvertent technology transfer	– 2000

Termination & Recovery Systems

- Cross Cutting Applications:
  - "Surface Systems" Technology Thrusts
    - Planetary recovery systems
    - Manned recovery systems
    - Low cost deorbiting systems

- Technology Transfer External to NASA:

Launch Systems

- **Critical Requirements**
  - Launch large rigid structures [20-30 Meter structures]
  - Minimize launch failures due to launch support equipment
  - Reduce weather related impacts on launch
  - Launch balloons > 40 million cubic feet in size
- **Enabled Science**
  - Antarctic night flights
  - Interferometers
- **Technologies under consideration**
  - New launch vehicles
  - Launch site improvements
  - New launch techniques
    - Static launch
    - Sea launch

Launch Systems

What is needed

- Large top-mounted experiment capability
- Static discharge protection
- Systems for performing launch at sea
- Portable launch site capability

Today's State of the Art

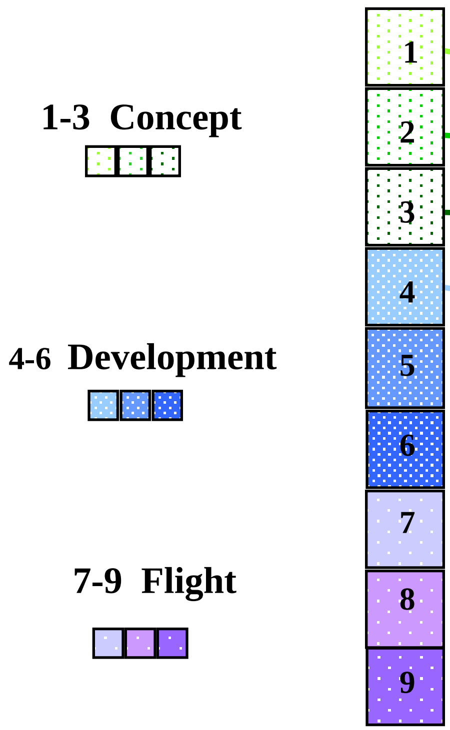
- Small top-mounted experiment capability
- Crane supported dynamic land launch

Technology Goals

- Stronger tethers for static launch
- Feasible concepts for sea launch

Launch Systems

Technology Required	*"Needed By"*
– Launch at sea	– 2007
– Portable launch site	– 2007
– Large top-mounted experiment capability	– 2005
– Static discharge protection	– 2005



Current Technology Readiness Levels

Launch Systems

- Cross Cutting Applications:

- Technology Transfer External to NASA:
  - Department of Defense
  - Commercial/Recreational Balloons

Operations Autonomy

- **Critical Requirements**
  - Ability to autonomously terminate/land
  - Automatic trending & control for critical systems (i.e. power, thermal, drift) when balloon is in ‘loss of signal’
  - Autonomous trajectory control

- **Enabled Science**
  - Any that require station keeping
  - All science because it reduces probability of termination for loss of signal

- **Technologies under consideration**
  - Remote Agents
  - State Modeling
  - Rule-based Expert Systems

Operations Autonomy

What is needed

- Autonomous termination & landing initiation
- Autonomous data dumps
- Autonomous trending of position (drift)
- Autonomous trajectory control
- Autonomous thermal control
  - Especially during ‘loss of signal’
- Autonomous power trending & control
  - Especially during ‘loss of signal’

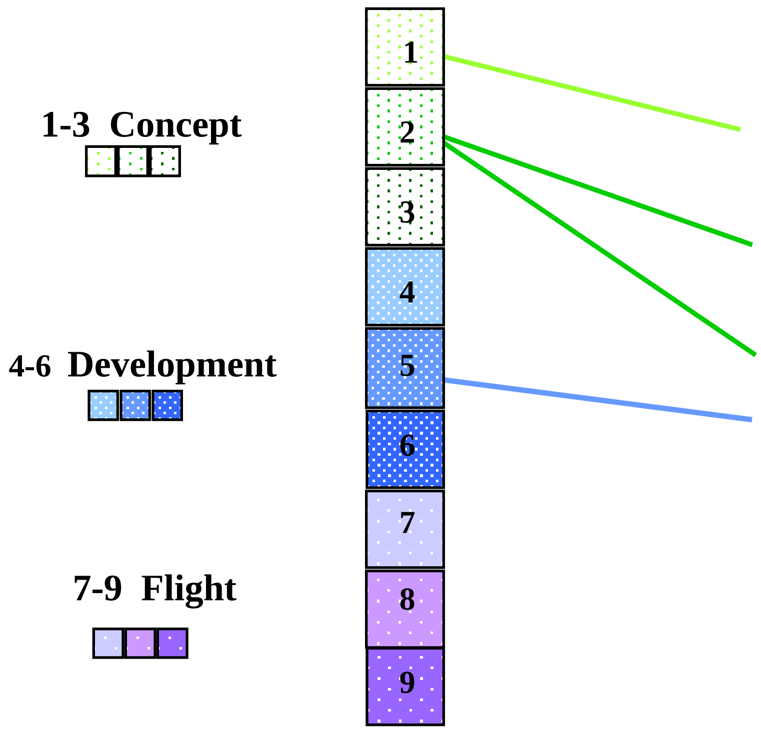
Today’s State of the Art

- Total ‘Lights Out’
- Autonomous trending is developmental

Technology Goals

- Initiate ground contact for downlinking data as on board buffers fill up by 2007
- Ability to make ‘decisions’ on best opportunities for capturing data given requirements by 2007
- Autonomous trending by 2003

Operations Autonomy



Current Technology Readiness Levels

Technology Required	***"Needed By"***
– Autonomous data capture decisions	– 2007
– Initiate ground contact for data dump when buffers full	– 2007
– Landing & Termination	– 2006
– Total autonomous trending & control of all systems	– 2003

Operations Autonomy

- Cross Cutting Applications:
  - LEO & planetary missions

- Technology Transfer External to NASA:

Acronyms

AO	Announcement of Opportunity
AGN	Active Galactic Nuclei
COTS	Commercial Off The Shelf
DLT	Digital Linear Tape
ESSP	Earth System Science Pathfinder
FOV	Field Of View
GB	Gigabytes
GFSC	Goddard Space Flight Center
GPS	Global Positioning System
IR	Infrared
JPL	Jet Propulsion Laboratory
LeRC	Lewis Research Center
LEO	Low Earth Orbit
Li-Ion	Lithium Ion
LOS	Loss Of Signal
MA	Multipurpose Access
MIDEX	Medium Explorers
NiH_2	Nickel Hydride
PI	Principal Investigator
RF	Radio Frequency
RTGs	Radial Thermal Generation
SMEX	Small Explorers
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOTA	State Of The Art
TB	Terabytes
TBD	To Be Determined
TDRS	Tracking and Data Relay Satellite
TRL	Technology Readiness Levels
UNEX	University Explorers

References & Assumptions

- Science & Technology input came from:
  - Attendees of the Prospects for 100 Day Balloon Flights Workshop, Greenbelt, MD, November 1996 [http://lheawww.gsfc.nasa.gov/docs/balloon/workshop96/]
  - Responses to the Strawman Payload Survey [http://lheawww.gsfc.nasa.gov/docs/balloon/workshop96/strawman.html]
  - ULDB Program Study Interim Report, April 1997 [http://lheawww.gsfc.nasa.gov/docs/balloon/ULDB_study/DAYBAL_4.html]
  - Attendees of the Ultra Long Duration Ballooning Technology Workshop, Greenbelt, MD, June 1997 [http://lheawww.gsfc.nasa.gov/docs/balloon/technology/workshop.html]
  - Attendees of the Second Ultra Long Duration Ballooning Technology Workshop, Greenbelt, MD, November 1998 [http://lheawww.gsfc.nasa.gov/docs/balloon/ULDBWorkshopGenInfo.html]
  - Balloon Working Group
  - Olympus Study Team

References & Assumptions

- Technology Readiness Levels
  - TRL definition provided from NASA Headquarters documentation
  - TRLs (current and required) were determined from technology experts and the science community
  - TRLs were also extrapolated from understanding the desired concept, development and flight schedule of Olympus

1997 ULDB Technology Workshop Attendees

Frank Baginski	George Washington University	Alan Jeffries	Interface & Control Systems
Sheila Bailey	NASA/LeRC	Dean Jorgensen	Pioneer Aerospace Corporation
Scott Barthelmy	USRA	Charles Joseph	Reemay, Inc.
Dwight Bawcom	New Mexico State University	John Kierein	KinetX, Inc.
Gail Bingham	Space Dynamics Laboratory	William Klein	Aerotherm Corporation
Otto Bruegman	ITMI	Lyle Knight	NASA/GSFC
Uma Bruegman	ITMI	Richard Kroeger	Naval Research Laboratory
James Cantrell	Space Dynamics Laboratory	Tim Lachenmeier	GSSL, Inc.
Richard Carter	Swales Aerospace	William Lampe	Cincinnati Electronics Corporation
Costas Cassapakis.	L'Garde, Inc	Gabriel Laufer	University of Virginia
Henry Cathey, Jr	Physical Science	Marvin Leventhal	University of Maryland
Edward Cheng	NASA/GSFC	Per Lindstrand	Lindstrand Balloons, Ltd.
W. Michael Chiville	CTA	David Lynch	Global Science & Technology
Charles Corey	Aerotherm Corporation	Steven Macintyre	MEDA, Inc
Dave Cottingham	GST	David Manion	Hughes STX
Wade Craddock	New Mexico State University	Neil Martin	NASA/GSFC
Kevin Dahya	Swales Aerospace	Brandon Mason	Sky Station International
Richard Dame	Mega Engineering	David McGill	Dimension Polyant
Thomas Davidson	New Mexico State University	William Munroe	Monroe Machinery Corp.
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Ingrid Desilvestre	NASA Headquarters	Robert Nock	NASA/GSFC/WFF
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Frank Douglas	Omitron	Ron Polidan	NASA/GSFC
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Michael DuVernois	Penn State University	James Rand	Winzen Engineering, Inc.
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Leon Eversfield	Lindstrand Balloons, Ltd.	Michael Seiffert	University of California, SB
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William Graham.	ILC Dover, Inc	Joel Simpson	NASA/GSFC/WFF
David Gregory	NSBF	Mark Skinner	Ball Aerospace
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Frank Hornbuckle	CTA	Michael Viens	NASA/GSFC
Elizabeth Hunt	Precision Fabrics Group, Inc.	Florian Walchak	Cortez III Corporation
Ronald Huppi	Utah State University	David Zillig	NASA/GSFC

1998 Second ULDB Technology Workshop Attendees

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James Abshire	Nasa/Goddard Space Flight	Roberto Ibbo	ASI-Italian Space Agency
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Pat Bahn	TGV Rockets	James Kalshoven	NASA/Goddard Space Flight Center
Sheila Bailey	NASA/Lewis Research Center	Miikka Kangas	University of California, Santa Barbara
Paul Baker	Global Science and Technology,	Viktor Kerzhanovich	Jet Propulsion Laboratory
Cheryl Bankston	NASA Marshall Space Flight	Jerry Knoblach	Space Data Corporation
Dwight Bawcom	PSL/NMSU National Scientific	David Kotsifakis	NASA/WFF
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